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AN EVALUATION OF POLYPROPYLENE FIBERS FOR USE IN CONCRETE

MATERIALS INFORMATION
ENGINEERING MATERIALS OFFICE

AN EVALUATION OF
POLYPROPYLENE FIBERS
FOR USE IN CONCRETE

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SUMMARY

A limited series of laboratory tests was carried out to evaluate the effect of the collated fibrillated polypropylene fibers on the properties of a 30 MPa conventional concrete and a latex modified concrete for bridge deck overlays.

The addition of the fibers had no significant effect on any of the test properties of the concretes. The tests did not evaluate the effect of the fibers on a restrained shrinkage. This effect can best be evaluated by a field trial (bridge deck overlay). However, such a field trial is not recommended until a method is developed for adding the fibers in a concrete mobile.

AN EVALUATION OF POLYPROPYLENE FIBERS FOR USE IN CONCRETE

A common method of bridge deck rehabilitation is to place a concrete overlay. In most cases, the concrete is modified by adding a styrene-butadiene latex at a dosage of 15% solids by mass of cement. Generally, the performance of the overlays is adequate but, although infrequently, shrinkage cracks do occur.

Anthes Equipment Ltd., Mississauga, Ontario has offered collated fibrillated polypropylene fibers for use in this Ministry's concrete. The fibers are manufactured by Fibermesh Company, Chattanooga, Tennessee. It is claimed that the addition of this type of fibers to concrete significantly improves shrinkage resistance, tensile strength, impact strength and permeability with no adverse effects on other properties.

This report describes the outcome of a limited series of tests carried out in the MTC Downsview laboratory, to determine the effect of the fibers on compressive strength, splitting tensile strength, modulus of elasticity, permeability, resistance to alkalies and salt, and shrinkage of concrete modified with the fibers. The tests were carried out during the period of April - August 1985.

Description of the Fibers

Collated fibrillated polypropylene fibers are distributed in Ontario by Anthes Equipment Ltd., Mississauga. They are available in lengths of 3/4", 1 1/2" and 2". The manufacturer states that their relative density is 0.91, tensile strength 80-110 ksi, ultimate elongation 15% and Youngs modulus 500 ksi. Their melting point is 320-340°F; both thermal and electrical conductivity is low.

The manufacturer recommends that the fibers be used at a rate of 1.0 kg per m3 of concrete. The length of the fibers used depends on the size of the aggregate - 19 mm long fibers are used for 9.5 - 16.0 mm aggregate, 25 mm for 16-25 mm and 50 mm for 19-38 mm.

Concrete Mixes

Two concrete mixes were made. One was a 30 MPa conventional, air entrained mix, and the other a latex modified mix. The coarse aggregate was a dolomitic limestone (Nelson Quarry) of 13 mm nominal maximum size and the fine aggregate a natural sand (Consolidated Sand and Gravel, Guelph) having a fineness modulus of 2.70. The cement was Type 10 from Canada Cement Lafarge, Woodstock plant.

The latex was Dow Modifier A.

The mix proportions and results of the standard fresh concrete tests are shown in Table A.

The specimens were cured and stored as described in Table B.

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The conventional concrete with the fibers required a smaller amount of the air entraining admixture to entrain the same specified amount of air as in the concrete without the fibers (7 ± 1.5%).

The conventional and the latex concretes with the fibers were more cohesive and showed a significantly lower slump than their corresponding concretes without the fibers. The workability of the concretes with the fibers was as good as that of the concretes without the fibers.

Hardened Concrete

Each of the two mixes without the fibers and the two mixes with the fibers were tested for compressive and splitting tensile strength at a number of ages, modulus of elasticity at 28 d, 48 h water absorption, rapid chloride permeability, and resistance to alkalies and salt. The test results and the test procedures, with the exception of the procedure for resistance to alkalies and salt, are shown in Table A.

The resistance to alkalies and salt was determined by exposing the specimens (100 x 200 mm cylinders) at 28 d to the following cycling: 3 d immersion in a 3% sodium chloride solution followed by 4 d drying at normal laboratory conditions. The concretes with and without the fibers were exposed to the cycling. The resistance was evaluated by comparing the splitting tensile strength of the specimens exposed to the cycling.

Compressive and Splitting Tensile Strength

The compressive and splitting tensile strengths shown in Table A are averages of three 100 mm diameter cylinders while the moduli of elasticity are averages of two 150 mm diameter cylinders. The 24 h compressive strength of the conventional mix with the fibers (Mix B) is approximately up to 10% higher than that of the mix without the fibers but at the later ages the difference between the compressive strength of the two mixes is reversed so that at 91 d the mix with the fibers is approximately 10% lower in strength than that without the fibers. The tensile splitting strengths show the same trend. The mix without the fibers (A) had a lower air content than that with the fibers (B) and this appeared to be the reason for the lower strength of the latter (B) at ages later than 24 h. There is an indication that the fibers had a beneficial effect on the 24 h strength of the concrete. The latex modified concrete tests show that the strengths of the concrete with fibers (D) are generally up to approximately 10% higher than those of the mix without the fibers (C).

Modulus of Elasticity

The difference between the Young's modulus of elasticity of the mix without the fibers (A) and that with the fibers (B), is not higher than approximately 2.5%. However, in both cases the mix with the fibers had a lower modulus of elasticity than that without the fibers.

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Water Absorption

The conventional concrete mixes indicate that the fibers increase the absorption while the latex modified concrete mixes indicate no difference in the absorption between the mix without and with the fibers.

Chloride Permeability

The conventional concrete as well as latex modified concrete mixes with the fibers had a lower permeability than their corresponding mixes without the fibers. The difference was greater in the latex modified concretes (13%) than in the conventional concretes (7.1%).

Resistance to Alkalies and Salt

The conventional concrete cylinders without and with the fibers had approximately the same splitting tensile strength after exposure to 9 cycles (age 91 d) as the corresponding cylinders made of the same mix and cured moist for 91 d. The latex modified concrete cylinders without and with the fibers had a somewhat lower splitting tensile strength after exposure to the cycling than their corresponding cylinders stored at normal laboratory conditions. When latex modified concrete is immersed in water, its strength decreases so this decrease in strength is attributed to the moisture, rather than to the effect of salt and alkalies in the concrete on the fibers.

Drying Shrinkage

The test was an unrestrained shrinkage test. The test results are shown in Fig. 1. The effect of the fibers was insignificant on the shrinkage of the conventional concrete. However, the latex modified concrete with the fibers shrank substantially more than that without the fibers. The shrinkage of the modified latex concrete was lower than that of the conventional concrete. Although this unrestrained shrinkage test is generally used to evaluate drying shrinkage of cementitious mixes, a restrained shrinkage test would be more appropriate for the evaluation of the effect of the fibers.

Conclusions

On the basis of this series of test, it can be concluded that the addition of 1 kg of the collated fibrillated polypropylene fibers modifies the properties of the concrete as follows:

a) It appears to increase somewhat the 24 h compressive and splitting tensile strengths, and to have no significant effects on the strengths at later ages of conventional concrete mixes. It appears to increase somewhat the strengths of latex modified concrete at all ages.

b) It probably lowers the static modulus of elasticity of conventional and latex modified concretes to an insignificant degree.

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c) It does not seem to have any effect on the water absorption of the concretes.

d) It decreases the chloride permeability of the concretes. The permeabililty of the conventional concrete was decreased from 3940 to 3660 and that of the latex modified concrete from 1338 to 1165 coulombs.

e) It has no significant effect on the unrestrained shrinkage of conventional concrete and it appears to increase the shrinkage of latex modified concrete.

The fibers are not affected by alkalies in the paste and long term immersion of the concrete in a 3% sodium chloride solution.

The laboratory pan type mixer distributed the fibers uniformly throughout the mass of the concrete.

Recommendations

The tests described above indicate that the addition of the collated fibrillated polypropylene fibers has no significant beneficial effect on any of the tested properties of the concrete. However, the unrestrained shrinkage test does not properly evaluate the effect of the fibers. The effect would be evaluated best by a field trial (bridge deck overlay) or overlaying a large concrete slab in the laboratory.

The permeability of conventional concrete is reduced too little to justify the use of the concrete with the fibers as a bridge deck overlay, even if the fibers significantly reduce its shrinkage. This concrete can be mixed and supplied by a ready mix truck where there would be no problem with the adding to and distributing the fibers uniformly throughout the mix.

There would be a problem with adding the fibers to a latex modified mix. This concrete is continuously produced by a concrete mobile; there is no provision in the mobile for adding materials such as the fibers at a uniform rate. A method for adding the fibers has to be developed. Because of this and an uncertainty that the fibers will reduce shrinkage cracking of bridge deck overlays to a significant degree, no further tests by the Ministry are recommended for the time being.

TABLE A MIX PROPORTIONS AND TEST RESULTS

	MIX NO.							
	A L 772/85		B L 777/85		C L 782/85		D L 785/85	
MIX PROPORTIONS (50 L BATCH)								
Coarse Aggregate, kg	47.1		47.1		39.5		39.5	
Fine Aggregate, kg	39.8		39.8		44.2		44.2	
Cement, kg	17.8		17.8		19.5		19.5	
Water (total), kg	9.0		9.0		3.9		3.9	
WRDA, mL	78.3		78.3		-		-	
Darex AEA, mL	4.8		4.3		-		-	
Latex, kg	-		-		6.1		6.1	
Polypropylene Fiber, (19 mm) g	-		50		-		50	
TEST RESULTS - FRESH CONCRETE								
Density, kg/m^3	2296	2300	2269	2255	2379	2379	2383	2376
Yield, L	49.5	49.4	50.1	50.4	45.0	45.0	44.9	45.1
Cement, kg/m^3	359.6	360.3	355.3	353.2	433.3	433.3	434.3	432.4
Eff. W/C	0.449	0.449	0.449	0.449	0.312	0.312	0.312	0.312
Slump, mm	90	90	75	75	180	190	130	145
Air, %	7.8	7.8	8.3	8.5	3.4	3.3	3.0	3.2
TEST RESULTS - HARDENED CONCRETE								
Compressive Strength, MPa (100 mm diameter cylinders, CSA A 23.2-9C)	1 d		12.6		13.2		15.8		15.2
	3 d		24.9		21.7		24.4		26.4
	7 d		30.1		28.1		31.6		32.9
	28 d		38.3		35.5		37.6		40.7
	91 d		44.8		40.5		44.5		46.6
	364 d								
Splitting Tensile Strength, MPa (100 mm diameter cylinders, CSA A 23.2-13C)	1 d		1.43		1.57		1.77		1.87
	3 d		2.68		2.43		3.07		3.50
	7 d		3.00		3.10		3.83		3.67
	28 d		3.70		3.60		4.90		4.87
	91 d		4.23		3.87		5.33		5.60
	364 d								
Modulus of Elasticity, GPa at 28 d (150 mm diameter cylinders, ASTM C 469-81)		33.6		32.8		27.8		27.4	
Water Absorption (48 h), % by mass (ASTM C 642-82)		5.1		5.5		1.2		1.2	
Rapid Chloride Permeability, Coulombs (AASHTO T 277-83I)		3940		3660		1338		1165	
Resistance to Alkalies and Salt; Splitting Tensile Strength, MPa	91 d		4.30		3.85		4.75		4.90
	364 d								

TABLE B CURING PROCEDURES FOR SPECIMENS

TEST	CURING AND STORAGE		
	FIRST 24 h	DEMOULDING AT	FROM DEMOULDING TO TESTING
Compressive Strength Splitting Tensile Strength Modulus of elasticity Absorption Chloride Permeability			
- Mixes A and B	Moisture room	23 ± 1 h	storage in moisture room
- Mixes C and D	"	"	storage in normal lab. air conditions
Unrestrained shrinkage			
- Mixes A and B	Moisture room	23 ± 1 h	storage in moisture room for a total of 72 h followed by storage at 23°C and 50% RH
- Mixes C and D	"	"	storage at 23°C and 50% RH
Resistance to alkali and deicing salt			
- Mixes A and B	Moisture room	23 ± 1 h	storage in moisture room for a total of 28 d
- Mixes C and D	"	"	storage in normal lab. air conditions for 27 d

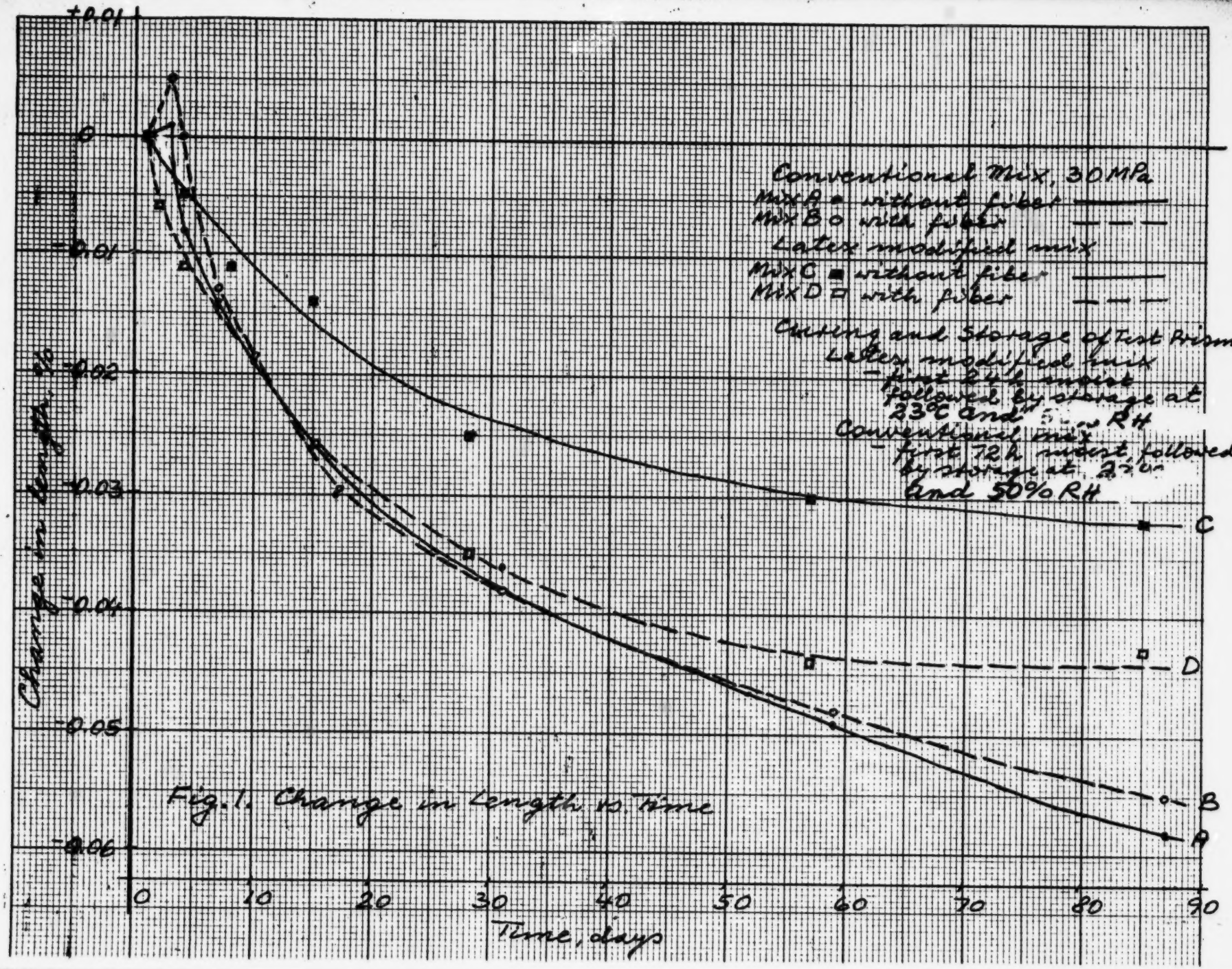

Fig. 1. Change in length vs. time